

Overview of Model-Based Systems Engineering Efforts to Evolve the Airspace Research Roadmap

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Outline

- Introduction
- Model-Based Systems Engineering (MBSE) Methodology
- Systems Models for Roadmap Development Lifecycle
- Planned Activities

Introduction

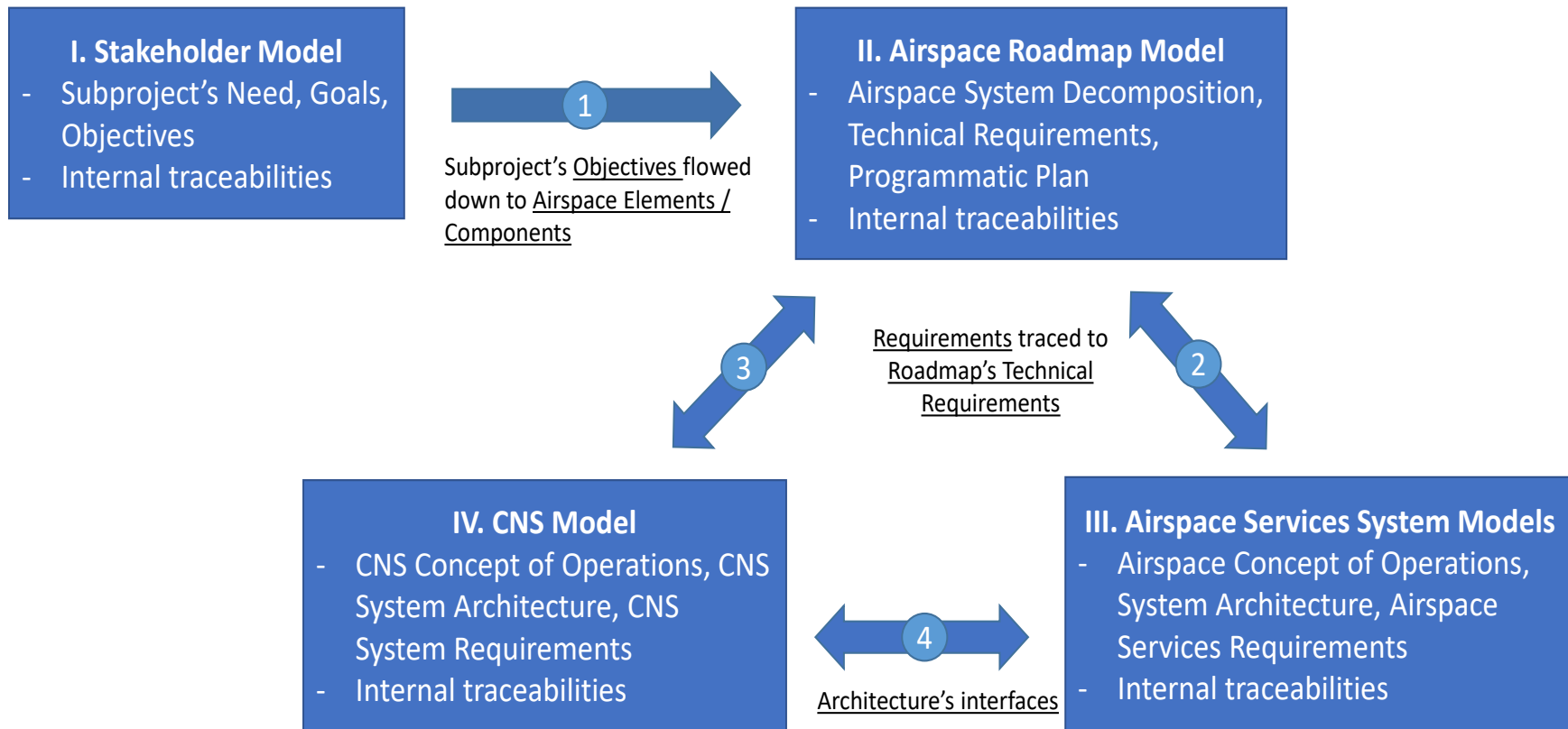
- NASA's Air Traffic Management-Exploration (ATM-X) Urban Air Mobility (UAM) Subproject is conducting research that **evolves UAM airspace** towards a highly automated and operationally flexible system of the future.
- The complexity of UAM airspace evolution requires a **plan** to effectively organize, integrate, and communicate NASA's research and development.
 - This planning tool is called **the UAM airspace research roadmap**.
 - Implemented through Model-Based Systems Engineering (MBSE) methodology

What is MBSE?

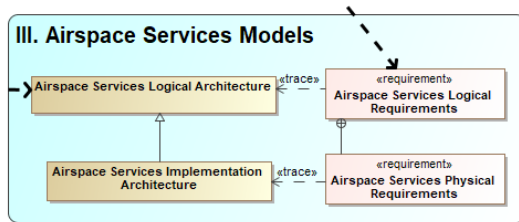
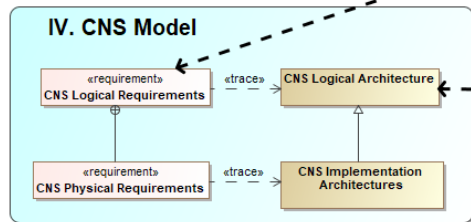
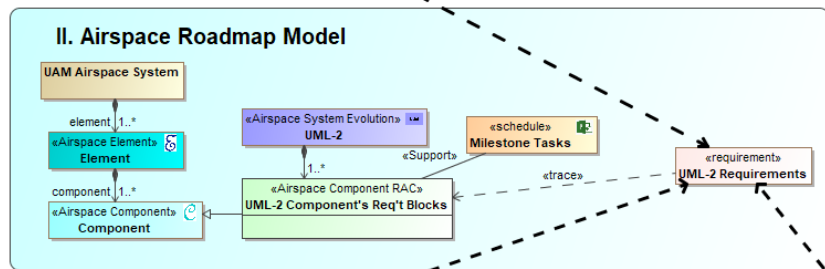
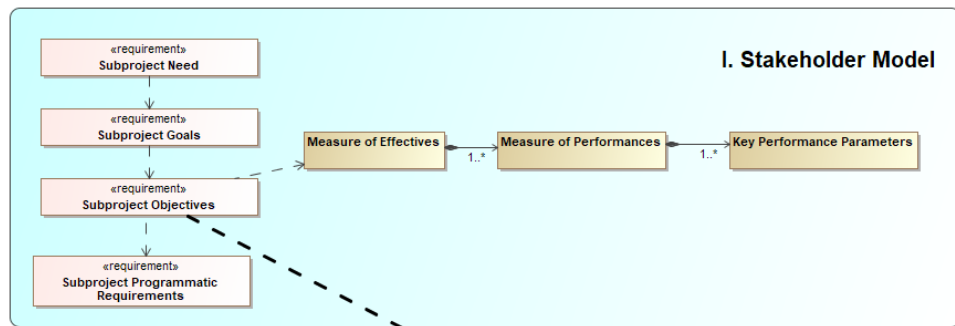
*“The **formalized application of modeling** to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases. MBSE is part of a long-term trend toward **model-centric approaches** adopted by other engineering disciplines, including mechanical, electrical and software.”*

The International Council on Systems Engineering (INCOSE) vision

Systems Models for Roadmap Development Lifecycle

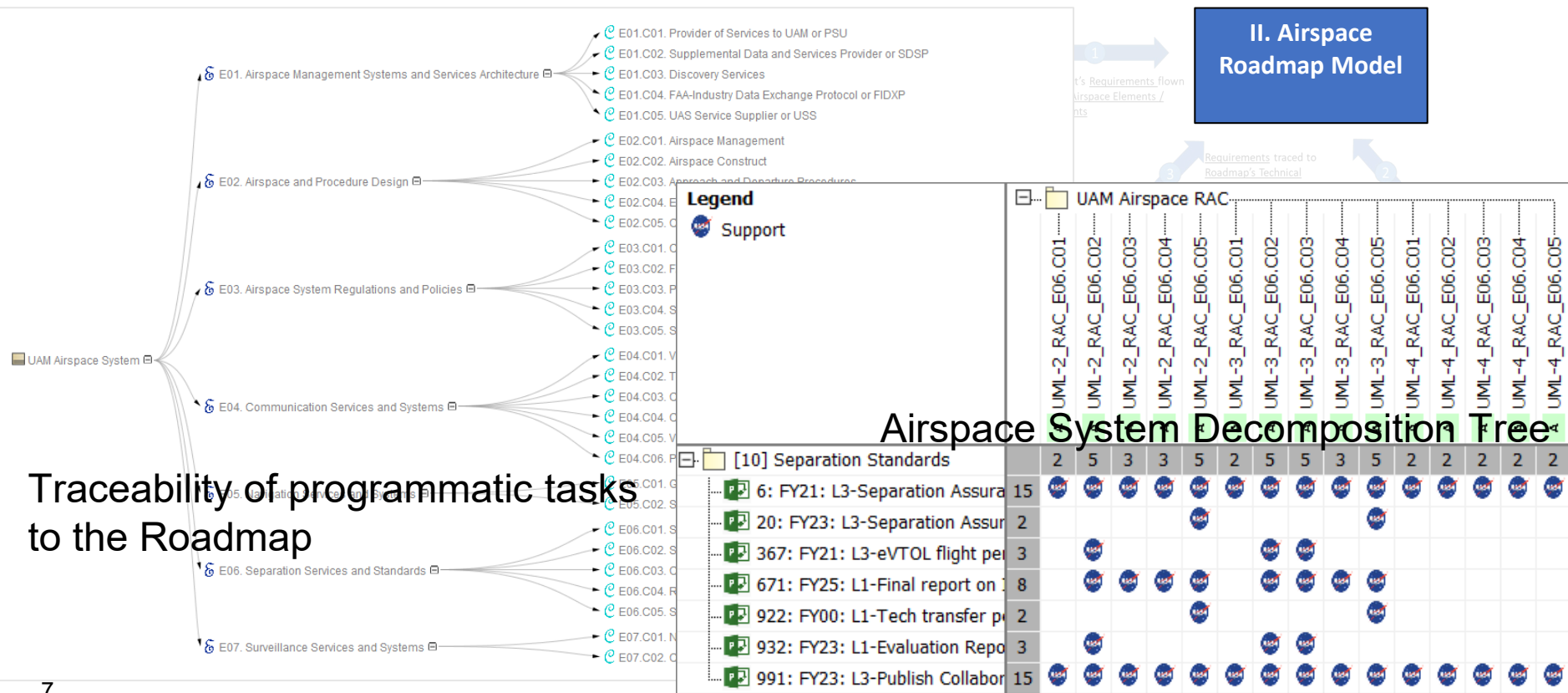


Systems Models for Roadmap (cont.)



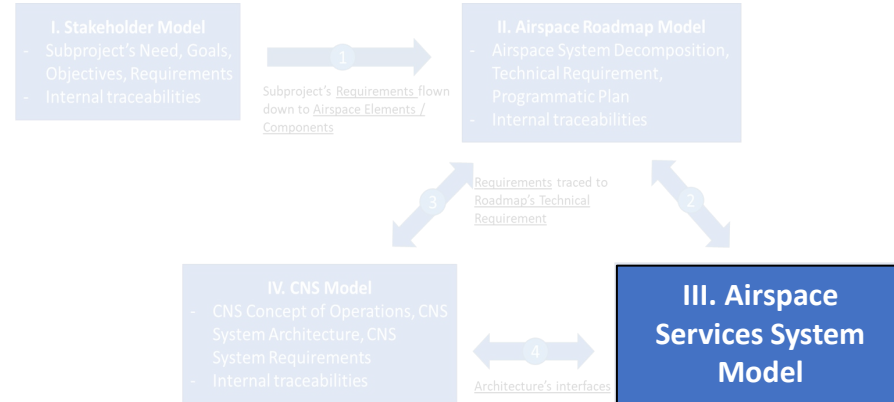
Meta-model definition showing structure and high-level dependencies within and between models.

Systems Models for Roadmap (cont.)



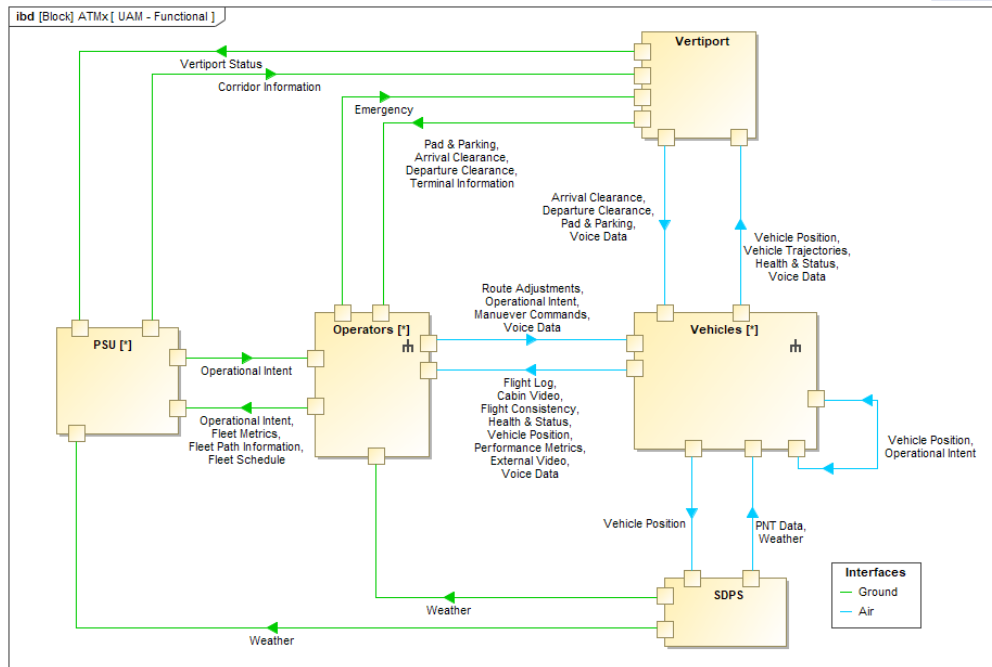
Systems Models for Roadmap (cont.)

0.1 - FAA UAM Roles		faa_FIDXP	faa_PSU	faa_PIC/UAM Aircraft	faa_UAM Operator	faa_SDSP
1.2.1 - NASA Physical Components		3	1	1	1	2
R&D X3_FIMS-AZ	1	●				
R&D DSS	1	●				
R&D X3_PSU	1		●			
R&D X3_Constraint Submitter	1					●
X3_Emulated Urban Layer	2	●				●
Simulated UAM Vehicle	1			●		
R&D Operator Interface	1				●	



Flowed down of logical architecture from FAA NextGen ConOps to NASA Simulation

Systems Models for Roadmap (cont.)



- I. Stakeholder Model**
- Subproject's Need, Goals, Objectives, Requirements
 - Internal traceabilities

1
Subproject's Requirements flow down to Airspace Elements / Components

- II. Airspace Roadmap Model**
- Airspace System Decomposition, Technical Requirement, Programmatic Plan
 - Internal traceabilities

3
Requirements traced to Roadmap's Technical Requirement

2

IV. CNS Model

4
Architecture's interfaces

- III. Airspace Services System Models**
- Airspace Concept of Operations, System Architecture, Airspace Services Requirements
 - Internal traceabilities

Functional CNS interface definition with associated data flows.

Systems Models for Roadmap (cont.)

I. Stakeholder Model

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












IV. CNS Model

III. Airspace Services System Models

- Airspace Concept of Operations, System Architecture, Airspace Services Requirements
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Architecture's interfaces

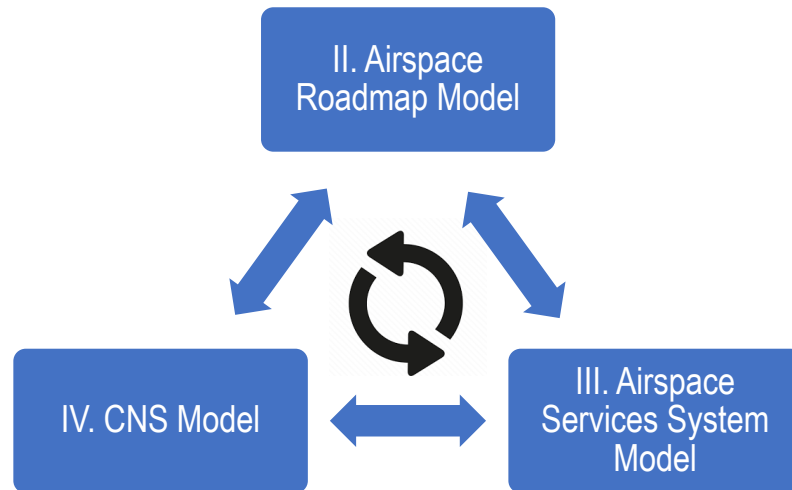
Data attributes defined for conveyed information. Used to drive external simulations. Requirements mapped to interfaces.

#	△ Name	Documentation	◇ MsgID	◇ MsgType	◇ MsgSize	◇ M	◇ N	◇ File	◇ MsgSrc	◇ MsgDes	◇ MsgPriority	
1	 Aerodrome Airspace Loading	Loading analysis for the aerodrome airspace	AAL	Triggered	400	1	TCP		A	PSU	Normal	
2	 Aerodrome Master Schedule	Full schedule for operations at Aerodrome. Includes all outbound and inbound flights scheduled as well as downtime for maintenance	AMS	Triggered	250	1	TCP		A	FM, PSU	Normal	
3	 Arrival Clearance	Clearance for aircraft to land at source Aerodrome	ACL	Triggered	95	1	TCP	100	1	ATC-A	AC, PIC	High
4	 Cabin Video											
5	 Corridor Information	Flight track details for fleet moving to and from aerodrome. Route tracks	FPI	Triggered	100	1	TCP		FM	A	Normal	
6	 Customer Information		C	Triggered	50	1	TCP		C		Normal	
7	 Customer Service Request	Customer request for flight services.	CSR	Triggered	50	1	TCP		C	FM	Normal	
8	 Departure Clearance	Clearance for aircraft to depart from source Aerodrome	DCL	Triggered	100	1	TCP	100	1	ATC-A	AC, PIC	High
9	 Detect & Avoid	Proximity warning data, automatic maneuvering. Can be Peer to Peer	DAA	Triggered	500	1	TCP	20	1	AC	AC, FM	High
10	 Emergency	Urgent request from aircraft. Mechanical failure or other anomalous situation	EM	Triggered	100	1	TCP	1	1	PSC	ATC-A, FM	Critical
11	 External Video											
12	 Fleet Metrics	General fleet information. Number of aircraft, type, charge capacity, efficiency, FAA documentation	FM	Triggered	200	1	TCP		FM	PSU	Normal	
13	 Fleet Path Information	Flight track details for fleet moving to and from aerodrome. Route tracks	FPI	Triggered	100	1	TCP		FM	A	Normal	
14	 Fleet Schedule	Full fleet schedule. All flights, to and from all destinations.	FS	Triggered	600	1	TCP		FM	FM	Normal	
15	 Flight Consistency	Position reports, waypoints, etc.	FC	Periodic	500	1	TCP	100	10	AC	ATC-A, PSU	High
16	 Flight Log	Passenger departure manifest, flight service performance, vehicle status, flight times, pad and parking information, pilot and uam operator sign	PFR	Triggered	100	1	TCP	100	1	AC, PIC	FM, AO	High
17	 Health & Status	Automatically reported data about the vehicle. Performance data, battery life, maintenance thresholds, general diagnostics	H&P	Periodic	700	1	TCP	100	10	AC	FM	High
18	 Maneuver Commands											
19	 Operational Intent	All information necessary for service. Waypoints, source, destination, clearances, payload, passenger manifest, timing, landing zones	FP	Triggered	1000	1	TCP	100	1	FM	AC, PSU	High
20	 Operations Request	Request from UAM operator to service an airspace area	OR	Triggered	50	1	TCP		FM	A	Normal	
21	 Operator Activity Detail	Description of new operator activity for planning and scheduling team to take into account when scheduling services	OAD	Triggered	100	1	TCP		A	A	Normal	
		Specific area of service for UAM operator in given										

Planned Activities

Iteratively evolve all models in a coordinated manner

- Revision of the roadmap's elements or components, and requirements to align with ConOps, systems architecture, and interfaces.
 - Refinement of requirement's ontology definitions
 - Characterization of validation maturity scales
- Revision of milestones and its traceabilities to Roadmap
- Tracking progression toward the Subproject's goal
 - Validated requirements
 - Gap analysis and course-correction plan



Track Roadmap Progression

NASA/TM-20210011098



Report: X3 Simulation with National Campaign-Developmental Test (NC-DT) Airspace Partners

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Roadmap Requirements Table

	UML-2	UML-3	UML-4
of Services to UAM (PSU)			
ental Data and Services Provider (SDSP)			
y Services			
stry Data Exchange Protocol (FIDXP)			
ee Supplier (USS)			
Integration			
Construct			
and Departure Procedures			
Procedures			
ncy Procedures			
ive Operating Practices or COP / Community Base..			
lations (FAR) / Code of Federal Regulation (CFR)			
nd Guidance			
anagement System (SMS) / Safety Risk Managem..			
ertification and Qualification			
ices			
y Services			
Services			
ncy Communications			
E04.C05. Vehicle-to-Vehicle Services			
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Requirement Count

■ To be traced
■ Traced to deliverables

Contract Number: GS00Q140ADU130 Delivery Order: 80GR019D0017, Deliverable 5

Reliable, Secure, and Scalable Communications, Navigation, and Surveillance (CNS) Options for Urban Air Mobility (UAM)

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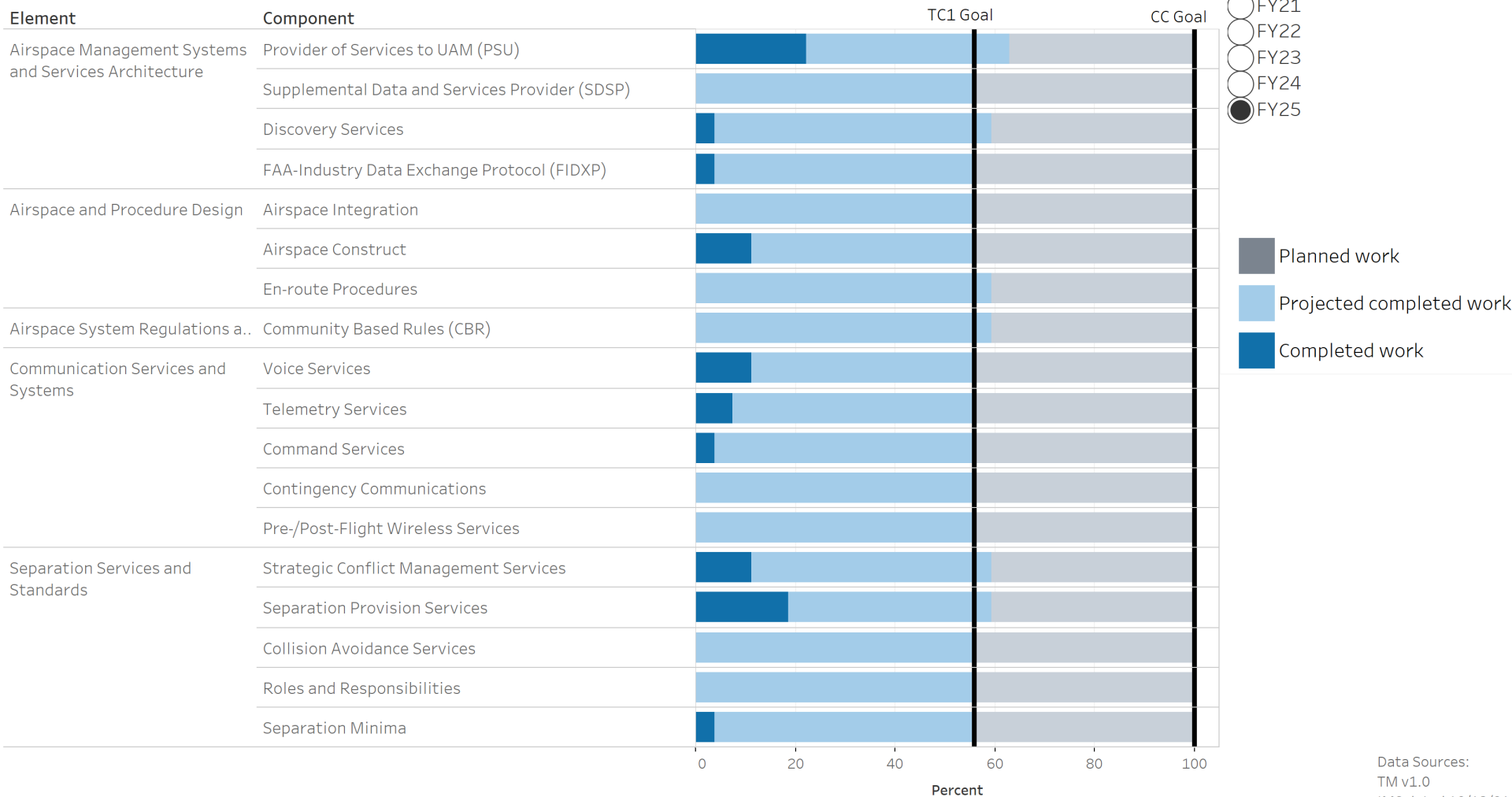
ICAROUS



A Brief Introduction

ICAROUS stands for Independent Configurable Architecture for Reliable Operations of Unmanned Systems. It is a software architecture that enables the robust integration of mission specific software

UAM Subproject Airspace Roadmap Progress Indicator





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